USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Predicting the Effectiveness of High-Intensity UV Lamp Technology as a Disinfectant for Various Quality Wastewaters Using the Collimated Beam Method

Focus Categories: WQL

Key Words: Water Quality, Ultraviolet Disinfection, Collimated-Beam, High-Intensity UV, Fecal Indicators, Spores, Virus

Duration: 03/01/99 through 02/29/2000 Year 1 of 2 year project

Federal Funds: $33,560 Year 1

Non-Federal Funds: $67,344

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Congressional District: First

Critical Regional Water Related Problems

Sewage and other forms of wastewaters (aquaculture, animal production) have traditionally been considered an undesirable product of society that must be disposed of in the most expeditious way. To protect the environment and public health, US regulations, require the treatment of wastewater to remove its organic composition and disinfection to kill its pathogenic (bacteria, protozoans, and viruses) content before it can be discharged into the environment (rivers, lakes, oceans) or reclaimed for beneficial uses. Historically, chlorine has been the disinfectant of choice. However, continued use of chlorine is now being discouraged for two reasons. First, use, transportation and storage of chlorine are hazardous activities and have resulted in many accidents. Second, use of chlorine has been shown to be detrimental to the health of people and aquatic organisms because of the formation of chlorine by-products which are toxic or are carcinogenic. As a result, there has been search for an alternative disinfectant.

A critical regional water problem is to find a disinfectant which is not only effective but safe for people who handle the system and safe for the environment. A relatively new disinfectant process which does not have the above problems associated with chlorine is the ultraviolet radiation (UV). Its primary advantages include the fact that UV radiation will inactivate all pathogens (UVC - germicidal UV), its use does not result in the formation of carcinogenic by products nor the presence of toxic residue in the treated water. Moreover, UV is generated on site and therefore excludes the dangers associated with the shipment and storage of a dangerous disinfectant. As a result of these properties, ultraviolet light technology has been called the environmentally friendly disinfectant (Acher et al, 1997). The effectiveness of UV technology as an effective disinfectant is based on the new lamp configuration design within the disinfection unit. Thus, UV systems built by different manufacturers are not equally effective. Moreover, there are some disadvantages in the use of UV such as high costs, photoreactivation, interfering factors in water (turbidity, suspended solids, absorbing compounds), uncertainties in measuring UV dose, and no residuals to be measured to monitor effectiveness of a system. Thus, more information is required before one can predict the effectiveness of UV as a disinfectant for the various types of wastewater. This study proposes to evaluate the most recent and more powerful UV light generated from a medium-pressure, high-intensity UV lamp (low-intensity and high-intensity lamps are compared in Table 1) as a disinfectant for various wastewater types. The proposed study will use the collimated beam method to evaluate the effectiveness of the polychromatic (many UV wavelengths) high-intensity UV light as a disinfectant (additional generated wavelengths disinfection impacts are well known at this time) by comparing its effectiveness with that of the traditional monochromatic (single wavelength - 254 nm) low-intensity UV light (well known disinfection impacts). To obtain valuable data, disinfection of various classes of microorganisms in various quality of wastewater will be evaluated. In summary, the success of this study will provide a procedure to predict whether any wastewater can be effectively disinfected by low-intensity versus high-intensity light technology.

Results, Benefits, and/or other information expected

Traditionally, pilot scale studies were required to determine whether a wastewater could be effectively disinfected by this new UV technology because a pilot study will integrate all factors involved in the effectiveness of that lamp system including the lamp characteristics, reactor design (applied lamp intensity, hydrodynamics), and vendor assumptions for determining their dose-response characteristics as well as the quality of the water. Our laboratory has been involved in evaluating these pilot and full scale studies (Moreland et al, 1997, Moreland, 1997, Moreland et al, 1996, Rijal and Fujioka, 1994) in which UV technology has been used to disinfect wastewater. However, pilot studies require planning, are expensive, require the establishment of a full operating unit on site and the results are specific to that location. We recently compared the results of a UV pilot field study and the results of exposing the same wastewater to UV disinfection using the standard, laboratory based collimated beam method. In that study we (Moreland, et al 1997) reported that pilot units (both low-intensity and high-intensity) dose-response curve results are virtually the same as collimated beam (low-intensity lamp) dose-response curve results for enterococci and fecal coliform. Based on these results, we evaluated the effectiveness of low-intensity UV light to disinfect many types of wastewater using the collimated beam method and developed a system of predicting the effectiveness of the full scale UV system to disinfect any of the potential waste waters. However, the significance of these studies are limited to using low-intensity UV light technology. In this proposed study we will obtain comparative information when high-intensity UV light technology (collimated beam) is used. There is no published information for collimated beam studies using medium-pressure, high-intensity UV lamp as the UVC radiation source (a recent visit to a UV system manufacturer pointed out that a medium-pressure, high-intensity UV lamp collimated beam could be built providing all necessary and proper safety).

Nature, Scope and Objectives

In most of the previous studies, the low-intensity UV lamps were used because these lamps produce most of their UVC radiation at 254 nanometers wavelength, which has previously been determined to be the wavelength to make nucleic acid non-functional and thereby disinfect microorganisms (Figure 1). Despite the initial success of using low-intensity UV light, it is known that low-intensity UV light has poor penetrability and therefore, many lamps must be used to treat wastewater when low-intensity UV lamps are use. To address this concern, the UV industry has recently developed a high-intensity UV lamp which theoretically can use fewer high-intensity lamps to produce the same germicidal UV dose as the low-intensity UV lamps. Besides having higher intensity, this new UV lamp produces light of many wavelengths, including those at 254 nanometers (Figure 2). The germicidal effects of these other wavelengths are not known.

The nature of this study will be to compare the effectiveness of high-intensity UV lamp with that of low-intensity UV lamp using the collimated beam method to disinfect many types of wastewater. This study will determine if the high-intensity UV lamp can be used in a collimated beam apparatus to predict its capacity to disinfect wastewater from different sources. Collimated beam method is the only method which can truly measure UV dose. As a result, the method allows for reproducible doses and can determine its affect on various wastewater with different quality. If an operating UV system has been properly designed and sufficiently tested, the results based on the pilot unit should closely approximate collimated beam results using the same treated wastewater. We have determined that such an operating UV system exist. Therefore, collimated beam results is an accurate and economical way of obtaining data which can be used to predict the effectiveness of applying UV systems to treat wastewater from different treatment plants. Animal and aquaculture wastewaters have relatively low ultraviolet transmittance (ability to allow UV radiation to pass through the liquid), as a consequence low-intensity lamp system (not very practical below 45 - 50 percent UV transmittance) would not be successful in disinfecting these wastewaters. High-intensity systems could be very successful in their disinfection.

The scope of this study will determine whether the many other wavelengths of UV light produced in the high-intensity UV lamp play a significant role in the disinfection of different types of microorganisms with different resistance to UV disinfection. The microorganisms to be tested include the traditional fecal bacterial indicators (enterococci, fecal coliform), one spore-forming bacteria (Clostridium perfringens), and one virus (FRNA bacteriophage). These microorganisms were selected because they are structurally and genetically different and represent groups of microorganisms with various sensitivities and resistance to UV disinfection.

The objectives of this study are:

1. To determine the differences in the effectiveness of high-intensity and low-intensity UV lamp in their ability to disinfect different classes of microorganisms.

2. To determine the contributing effect of different radiation wavelengths on disinfecting different microorganisms.
3. To determine how the quality of wastewater impacts on the effectiveness by which low-intensity and high-intensity UV light disinfects microorganisms.
4. To determine whether the results of collimated beam method using high-intensity UV light can reliably predict the success of applying high-intensity UV technology to disinfect various different types of wastewater.